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APOLLO SYSTEMS DEPARTMENT

GENERAL ● ELECTRIC

HOUSTON, TEXAS   **TECHNICAL INFORMATION RELEASE**   TIR 741-MED-4025

FROM D. G. Fitzjerrell	TO J. A. Rummel, Ph.D./DB6		
DATE 9/9/74	WORK ORDER REF: DM-109T	WORK STATEMENT PARA: NAS9-12932	REFERENCE:

SUBJECT

Design Specification for the Whole-Body Algorithm

The Design Specification for the Whole-Body
Algorithm provides the necessary requirements
and guidelines for the construction of a com-
puter program of the Whole-Body Algorithm. The
details of this program (TIR 741-MED-5008), and
its operation will be published, after coding
is complete, in the form of a program descrip-
tion and user's instructions (TIR 741-MED-5009).
This specification is subsequent to and should
be used in conjunction with TIR 741-MED-3058 –
Study Report, The Development of a Whole-Body
Algorithm, by Franklin J. Kay, Ph.D.

D. G. Fitzjerrell

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Attachment
/db

CONCURRENCES

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ASD 4028

I. GENERAL REQUIREMENTS, OBJECTIVES, AND GUIDELINES FOR DEVELOPMENT OF THE WHOLE-BODY ALGORITHM

1. The primary objective for the initial phase of the development of a whole-body algorithm is to study the physiological interactions of major body subsystems.

2. The basic requirement for satisfying this objective is to model these interactions and to simulate the total body response to selected stresses.

3. The minimum subsystem models required to effectively simulate the response to the stresses of interest are:

   a) Cardiovascular (exercise/LBNP/tilt)

   b) Respiratory (Grodins Model)

   c) Thermoregulatory (Stolwijk's Model)

   d) Long-term circulatory fluid and electrolyte (Guyton Model)

4. The whole-body algorithm must be capable of simulating the response to the following stresses:

   a) CO_2 inhalation

   b) Hypoxia

   c) Thermal environment

   d) Exercise (sitting and supine)

   e) LBNP

   f) Tilt (changing body angles in gravity)

5. The basic approach to simulating the response to these stresses will be to design for long term effects and short term effects. The long term effects will be simulated by the Guyton model. All short term effects and transient conditions will be simulated by the short term models (cardiovascular, respiratory, and thermoregulatory). The ground rules for this approach are as follows:

    a) the long term model will be a supine representation; therefore, short term models will be capable of being initialized from a supine position and matched with the long term model supine conditions for parameters being passed to initialize the short term models.

    b) short term models will retain control until steady-state conditions are reached and be capable of reinitializing the long term model at the new steady-state conditions. This may require continuous or periodic passing of important parameters to the long term model so that it "follows" the transient to avoid a step change and/or simulation time loss.

    c) only 1-g simulation of the stresses will be required, but the structure for addition of zero-g simulation will be provided.

6. Validation of the whole-body algorithm will be limited to 1-g simulation of the stresses listed in (4) above. Validation

will consist of comparing the results of the whole-body
algorithm simulation of the stresses as compared to available
experimental data representing the response of the modeled
subsystems to similar stresses with the emphasis upon the
interaction between these subsystems and/or the "whole-body"
response.

7. Reporting requirements for the whole-body algorithm develop-
ment will emphasize the problems of simulating multi-interact-
ing systems and interfacing large subsystem models. The impor-
tance of interacting major body subsystems and the physiologi-
cal representation of these interactions as represented in the
whole-body algorithm will be discussed in detail. The general
emphasis on reporting the development of a whole-body algorithm,
in fact, will remain primarily on the approach, solution, and
unresolved problems associated with interfacing and simulating
the physiological interaction of major body subsystems.

II.   THE FIVE TECHNICAL APPROACHES AND ASSOCIATED LEVELS OF DIFFICULTY

In the preliminary search for a design approach to the whole-body algorithm, five basic approaches were identified and a level of difficulty was assessed for each. These five approaches with their associated level of difficulty are described in the following paragraphs and related to the general requirements of the whole-body algorithm. It is recognized that other approaches and variations of these which have been identified may exist, however, temporal constraints require that a selection be made from among those already identified.

The first approach which has already seen limited uses in the Skylab data analysis project is shown in Figure 1 and represents the first level of difficulty. The models which are designed to simulate the short term transient response to an experimental stress are initialized by the long term model. The current success of this approach in meeting the requirement of major physiological subsystem interaction is limited to initializing a short term cardiovascular model. Also, long term effects are not changed by performance of the experiment since communication is unidirectional; therefore, this approach does not meet the general requirements.

The second approach suggested is the coupling of each subsystem model with all other models pairwise as shown in Figure 2. The operation of these models in this approach is limited to two at any given time. Although this approach suffers from the same

interfacing limitations between the long term cardiovascular model and the short term thermoregulatory and respiratory models, it does require a maximum amount of interfaces to be completed. This approach does not meet the basic requirement of a single system to represent whole-body response to stress. It does, however, allow a logical extension which will be considered as the fourth approach.

The third approach, as shown in Figure 3, separates the short term subsystems models and the long term cardiovascular model with a single interface structure between the two. This approach minimizes the number of necessary interface points, and adequately satisfies the general requirements of the whole-body algorithm. The separation between long and short term models is necessary in the numerical sense because the integration step size must be small in the short term model in order to accurately simulate the transient responses to short term experimental inputs. In the long term model integration step size must be orders of magnitude larger in order to maintain a reasonable simulation time. The combined short term models will be utilized only when experiment simulations are required or when simulating transients in the environment and the effects are passed back to the long term model at a rate consistent with numerical stability.

The fourth approach, as shown in Figure 4, employs the coupled systems of approach two for operation of all models simultaneously. This approach requires full interfacing of all existing short term and long term models. This approach contains all the elements of

a complete whole-body algorithm within the limitations of existing subsystem models, and more than satisfies the general requirements. The interface points to be considered above those required for approach three lack sufficient definition to be easily implemented and in that respect represents an overdesign to meet the general requirements.

The fifth approach is to build a single model from existing elements of the four subsystem models. This would produce a unified program capable of responding to transient inputs and long term effects with one set of compartments and initialization data. This approach, although desirable from many points of view, appears extremely difficult and violates the necessary time constraints, as it has been estimated as a five-year project.
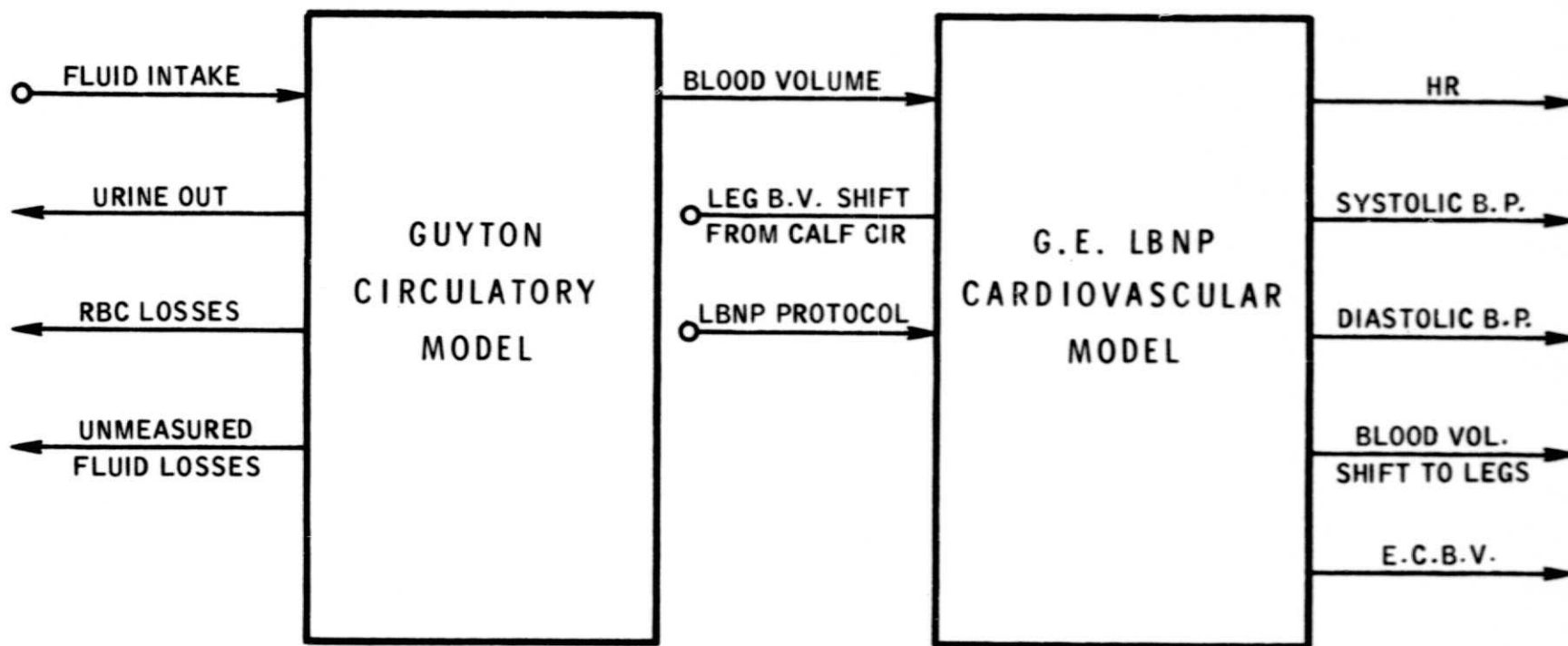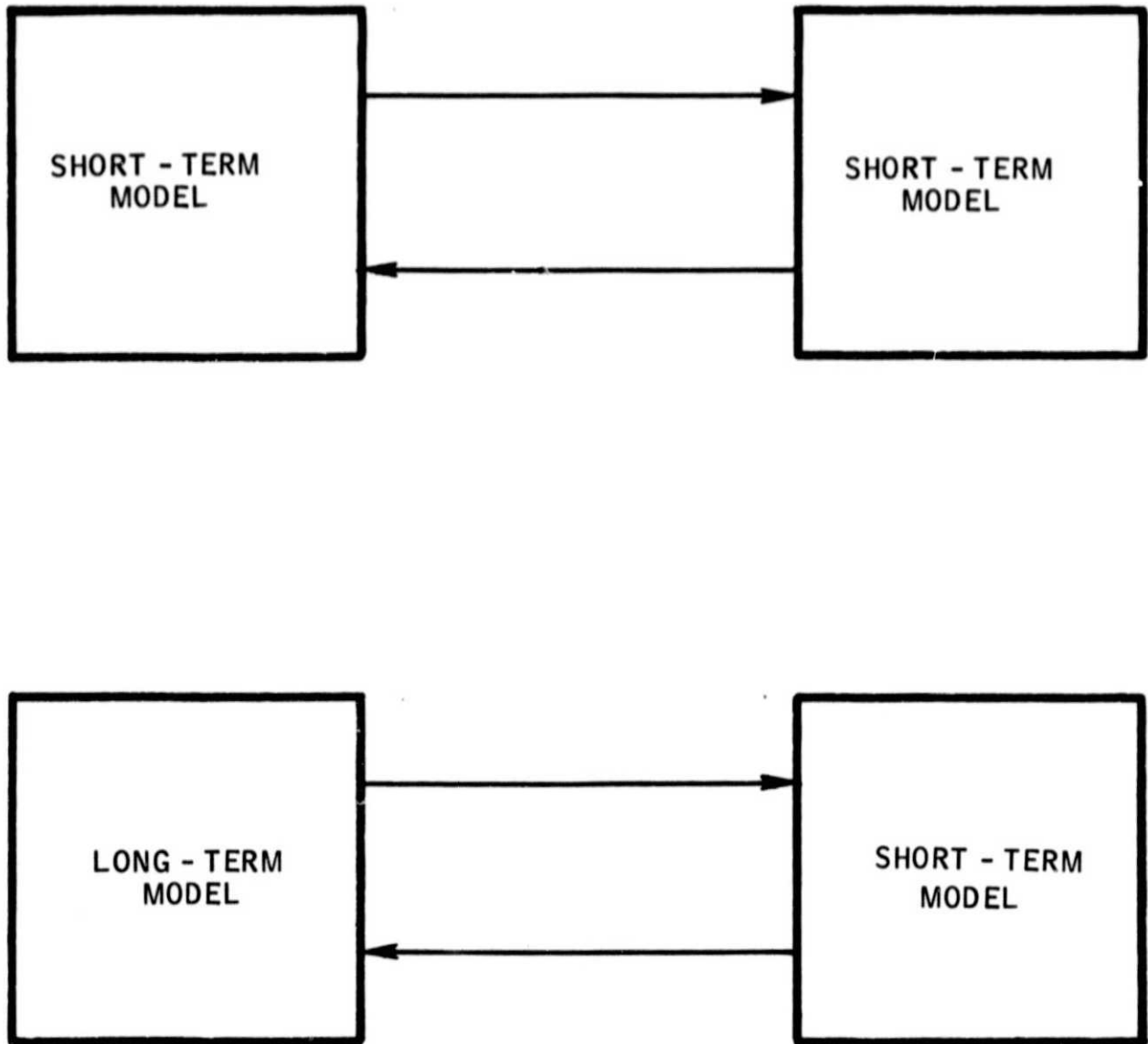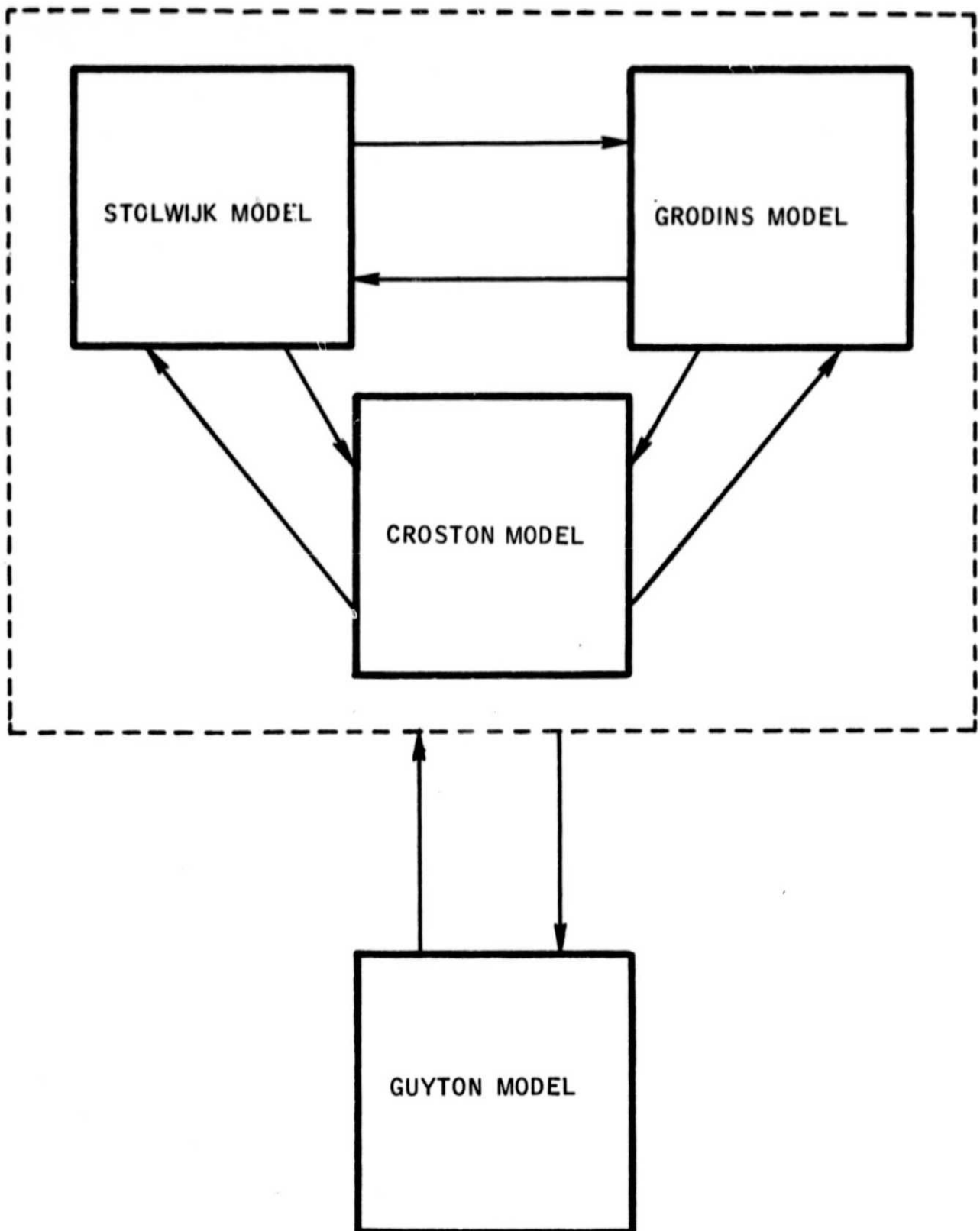
FIG. I LEVEL I

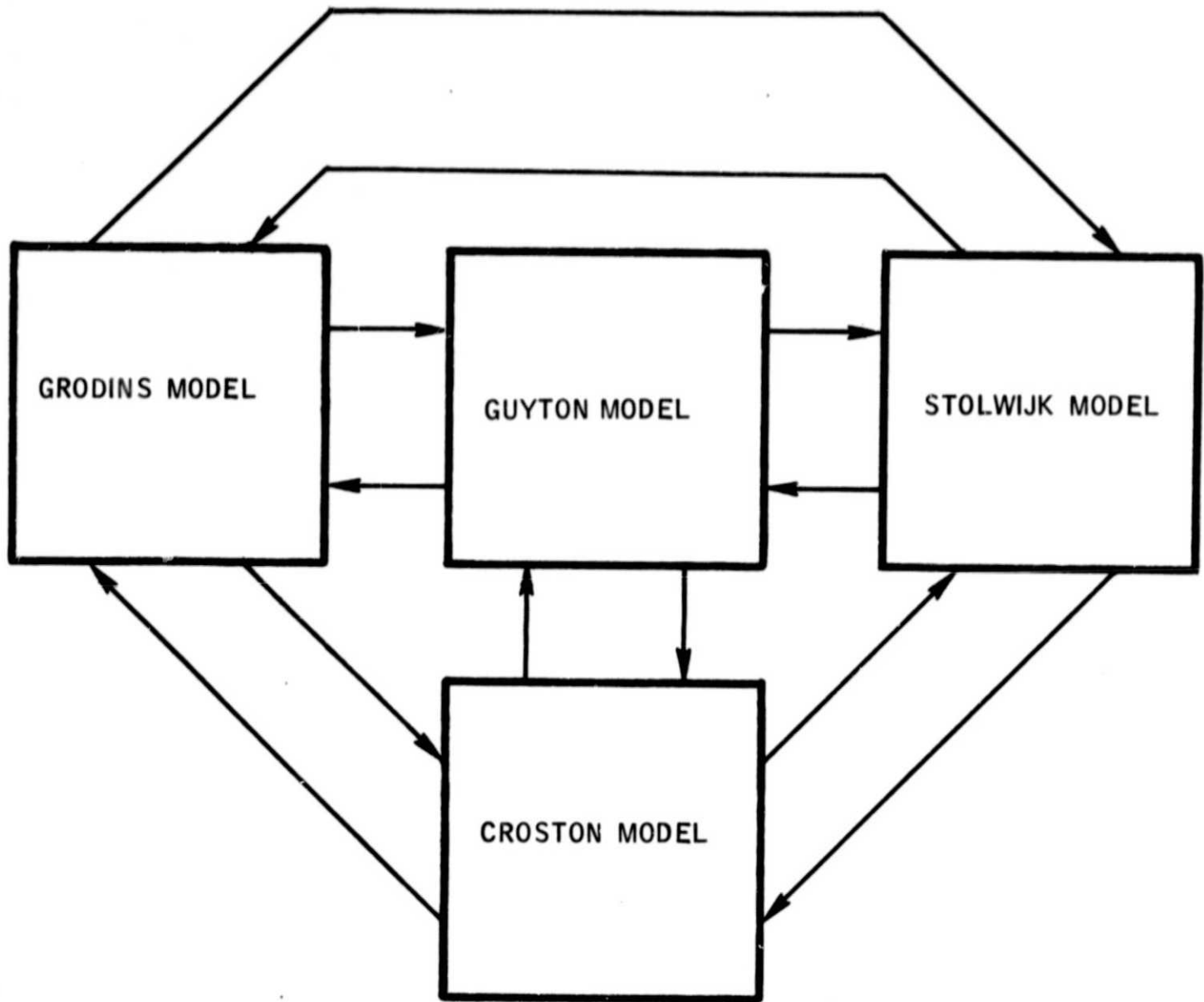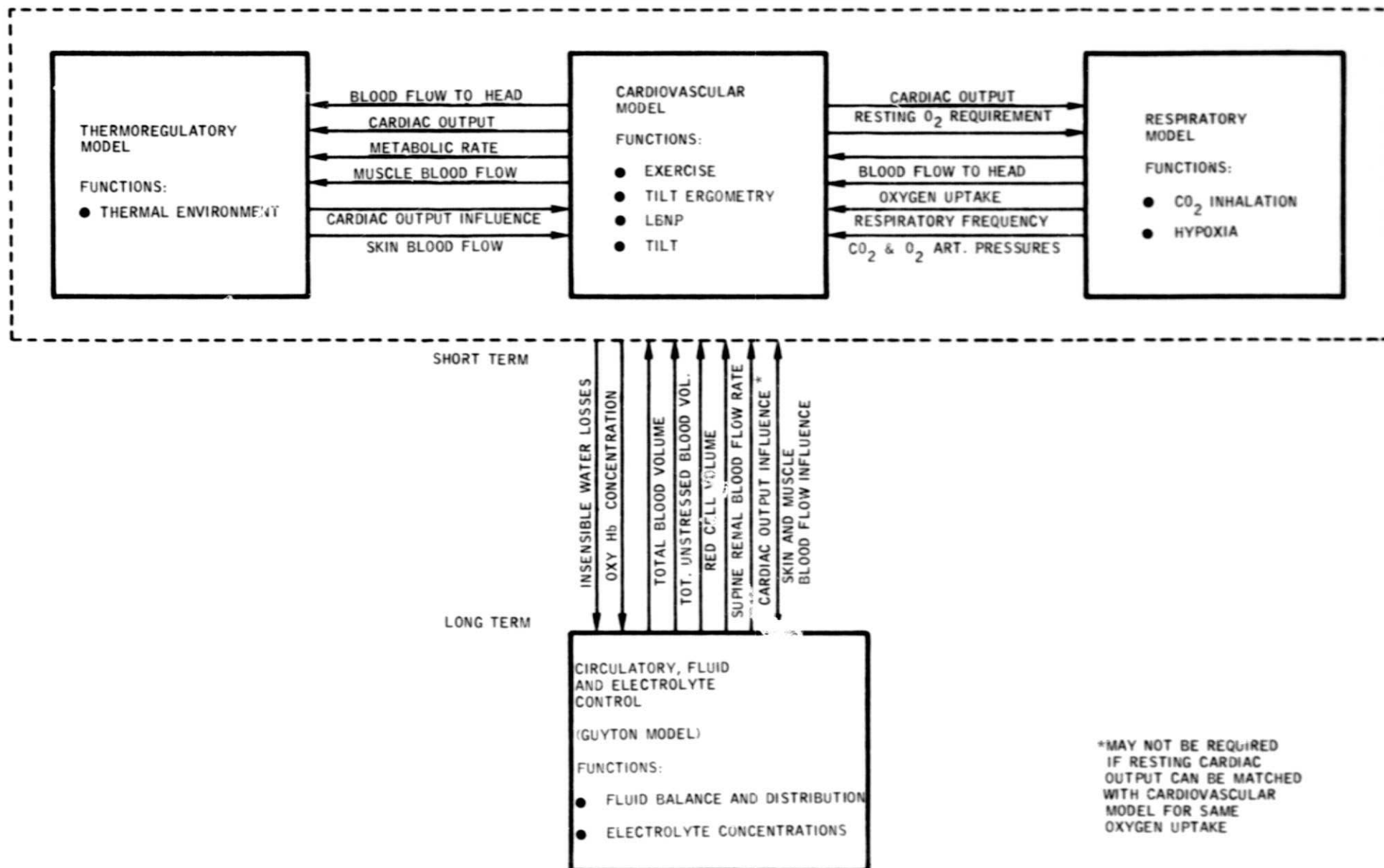FIG 2 LEVEL 2

FIG 3   LEVEL 3

FIG 4 LEVEL 4

III. APPROACH CHOSEN AND WHY

The approach chosen as a basis for the design of the whole-body algorithm is shown in Figure 3 and represents the third level of difficulty. This approach appears to be the least difficult to adequately meet the general requirements and as such is the optimal approach. The combination of the three short term subsystem models to operate together should be more simple to implement mechanically since integration step sizes are more compatible and each model will operate within its present compartmental structure. The initialization data for the combined short term models will be passed only when transient experimental conditions are input and passed back to the long term model as often as required for numerical stability in the Guyton model. This should minimize the long term - short term interface and still allow bidirectional communication. Hopefully, due to these considerations the approach which has been chosen will adequately satisfy the requirements at the lowest level of difficulty. Figure 5 presents a preliminary system design for this approach.

FIGURE 5. PRELIMINARY SYSTEM DESIGN